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PHYSIOLOGICAL FACTORS OF MINE VENTILATION

BY

R. R. SAYERS

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PHYSIOLOGICAL FACTORS OF MINE VENTILATION[1]

By R. R. Sayers[2]

INTRODUCTION

The main physiological factors of ventilation in mines where satisfactory air conditioning has not been or can not be carried out are (1) the development of silicosis among miners breathing the silica dust produced in the course of mining operations, and (2) the contraction of various diseases due to abnormal air conditions. The second factor can be divided into the effects of (a) abnormal temperatures and humidities and of (b) various gases that may be produced in mines under certain conditions. The following is a summary of recent information on these two factors.

SUMMARY OF RECENT INVESTIGATIONS ON SILICOSIS

Australia.- In Western Australia, in the course of an investigation of the pulmonary conditions of mine employees, 4,067 men were examined, 3,039 at Kalgoorlie and 1,028 at nine other mining centers throughout the State. A mobile laboratory with a portable X-ray plant was despatched from Kalgoorlie to these other centers. The men examined were working mine employees, with the exception of 48 ex-miners. A complete medical examination was made, and an X-ray picture of the chest was an important feature of the examination; an industrial history was also taken. For a number of examinees certain special physical measurements were recorded.

The results of the investigation showed that of the 4,067 men examined, 798, or 19.6 per cent, presented definite evidence of pulmonary silicosis, and 155, or 3.8 per cent, gave evidence of tuberculosis; 12 of the latter group showed tuberculosis without silicosis. Surface workers numbered 1,759; 6.6 per cent had silicosis, 1.5 per cent silicosis plus tuberculosis, and 0.3 per cent tuberculosis without silicosis. Of surface workers without previous underground experience those engaged in dry milling showed the highest incidence of silicosis; 9.6 per cent were affected, in contrast to 2.2 per

1 Report of the chairman of the Subcommittee on Physiological Factors of the Committee on Ventilation of the American Institute of Mining and Metallurgical Engineers, at the February, 1929, meeting in New York City. The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgement is used: "Reprinted from U. S. Bureau of Mines Information Circular 6196."

2 Chief surgeon, U. S. Bureau of Mines; surgeon, U. S. Public Health Service.

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cent of the employees engaged in wet milling without any dry mill experience, and 2.0 per cent of others who had no wet or dry milling experience.

Underground workers numbered 2,308, of whom 23.3 per cent had silicosis, 5 per cent silicosis plus tuberculosis, and 0.3 per cent tuberculosis without silicosis. No fewer than 51.5 per cent of persons engaged in developing and 39.2 per cent in stoping were affected with silicosis or tuberculosis, in contrast with 8.4 per cent of persons without stoping or developing experience. The predominating influence of underground work in causing silicosis is shown by the group of men who had worked 21 to 30 years in the industry. Of those who had done no underground work during this time, 7.2 per cent were found to be suffering from silicosis. During this time the percentages of groups affected, classed according to length of underground service, were as follows: None to 5 years' underground work, 13 per cent; 6 to 10 years' underground work, 21 per cent; 16 to 20 years' underground work, 44 per cent; and 26 to 30 years' underground work, 68 per cent.[3]

Of 1,595 air samples taken in the mines, 35 per cent had dust counts in excess of the arbitrary safety limit of 300 particles per cubic centimeter. Blasting was being done during the shift, instead of at the end when the workings are vacated. High blood pressure was more common among silicotics than others and albuminuria was more common; but silicosis alone, while not affecting body weight, did reduce the vital capacity. The Miners' Phthisis Act, 1922, compels miners to submit to examination and to possess a health certificate permitting them to work; if found with tuberculosis, a miner is prohibited from employment; if with silicosis, he is informed that further work may be detrimental to his health. No information is given as to whether compensation accrues; but evidence was forthcoming from the Mine Workers' Relief Fund that in 10 years 721 applications for relief have been granted, 92 per cent being for pulmonary diseases. Of these 721, 511 are dead; the average time between incapacity and death was 21 months.[4]

Canada.- During the year April 1, 1926, to April 1, 1927, a survey of silicosis in the Porcupine group in mines in Northern Ontario was made under the auspices of the mine operators in compliance with the amendment to the Miners' Phthisis Act of April 8, 1926, bringing silicosis under the status of a compensable industrial disease. Approximately 4,000 miners were examined for tuberculosis, silicosis, or both. As a result, 94 claims of silicosis were submitted for compensation. Using the South African nomenclature, of these 94 cases, 39 were anteprimaries, 28 primaries, and 27 secondaries; in

3 Nelson, W. T., Report on an Investigation of the Pulmonary Conditions of Mine Employees, Western Australia, During the Years, 1925-1926. Commonwealth of Australia, Dept. Health, Ser. Pub. (Div. Indust. Hyg.) No. 5, 1927. Quoted from Journ. Indust. Hyg., vol. 10, No. 7, September, 1928, p. 171 Abstracts.

4 From same reference as 3 but quoted from Bulletin of Hygiene, London, vol. 3, No. 2, November, 1928, page 952.

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addition, 247 men showed either positive or probable tuberculosis.[5]

England.- The difference in the harmful action of various kinds of silica dust is pointed out by Hefferman[6] as being indicated by experience with silica dust from materials when used industrially, such as millstone grit, pocket silica sand, ganister rock, and chert. The dust from the millstone grit, which contains 98 per cent of silica, is well known to be injurious and to cause a high phthisis death rate among gritstone workers. Pocket silica sand presents a different picture. This material is used for making refractory bricks; the exposure to dust is considerable; the clothes of the workmen, when beaten, emit clouds of dust, and the girls wear caps to keep the dust out of their hair. Analysis shows the material to contain from 84.9 to 89.9 per cent silica, present as about 78 per cent quartz. Yet no unusual death rate from pulmonary diseases occurs among these men. The conclusion is that the dust for some reason is not injurious. Interest in this matter attaches to the statement that although there is nothing that can properly be styled argillaceous matter, each grain of quartz has a pellicle of kaolinitic material. No attempt is made to explain how this attribute renders the silica particles innocuous in the body. The working of ganister gives rise to a dust recognized to cause truly appalling death rates from phthisis.

Finland.- A paper, based on the histories of 69 natives of Österbotten, Finland, who returned home after mining in South Africa and North America, was published under the title of "Contribution to the knowledge of the roentgenological appearance of silicosis."[7] The X-ray findings of the chest were grouped in four sets; one with enlarged and increased hilum structure; two with increased linear structure; three with small-mottled structure; and four with big-mottled structure. The first two may occur in varying degrees together or with the last two. The general character of the lung structure must determine the diagnosis. But X-ray shadows are not characteristic only of pneumonoconioses; they only confirm a history of suspicious miners' lung; they do not constitute decisive factors for the differential diagnosis of silicosis. Even the massive shadows of group four may occur in pulmonary tuberculosis without silicotic complication, although they are seldom so symmetrical. Intensity of dust exposure and quality are more important than duration of exposure. Once established, dust-lungs remain fairly stationary for many years after home-coming - unless tuberculosis supervenes. Dyspnea is correlated positively with X-ray changes, although exceptional cases occur.

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5 Hague, O. G., and McBain, R. W., Silicosis as an Industrial Hazard in Ontario Gold Mining. Am. Jour. Roentgenol., vol. 18, October, 1927, pp. 315-322. Quoted from The Journal of Industrial Hygiene, vol. 10, No. 6, June, 1928, pages 147-148.

6 Hefferman, P., Silicosis in Derbyshire. Derbyshire County Council Ann. Reports County M.O.H. and School Med. Officer for year 1926. Appendix 11, pp. 137-49. Quoted from Bulletin of Hygiene, vol. 3, No. 3, March, 1928, page 227.

7 Öhman, R. C., Contribution to the Knowledge of the Roentgenological Appearance of Silicosis. Acta Radiologica, vol. 9, 1928, pp. 266-286. Malm's Hospital, Jakobstad. Quoted from Bulletin of Hygiene, vol. 3, No. 11, November, 1928, page 954.

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France.- The results are reported of an examination of 24 men who as quarriers and dressers of gritstone for use as paving stones, were exposed for years to dust inhallation.[8] Most of the men exhibited definite impairment of the lungs, with abnormal radiographic appearances. General health was not apparently affected, except that two cases were tuberculous. Investigation of mortality records for some 50 years disclosed that in this occupation 56 out of 68 deaths (85 per cent) were due to respiratory diseases, all of which, previous to 1900, were ascribed to tuberculosis, but more accurate certification in recent years has divided the deaths between bronchitis and tuberculosis.

Germany.- The director of the Tuberculosis Dispensary at Schweitzingen, Baden, in consequence of some cases of silicosis from sandblasting which had come before her, proceeded to the detailed examination of 26 men thus employed.[9] The findings were surprisingly bad. Thus in 16 cases the X-ray findings were pronounced. In 2 of these cases, tuberculosis and pneumoconiosis were found; in 2 tuberculosis without special signs of silicosis; and pneumononiosis was evident in 10, 7 of which had changes of great severity and extent.

The time of exposure to the effects of the dust were in all relatively short - in one 8 years, in another 6, in two 4 years, and in all the others was under 3 years. The older the workers were, the more marked was the evidence of injury. This point has a practical bearing, as it suggests exclusion of old men from the work.

Details as to symptoms present are given of several cases. Surprise is expressed by the author that the men should have continued to work, and she attributes the fact to the high wages received.

Physical signs, even when X-ray examination showed marked changes, were comparatively slight. Bronchitic sounds were often absent. Chest expansion was very poor. In severe cases the X-ray appearances showed both lungs everywhere permeated by a network of shadows. In other cases the shadows involved only certain portions of the fields - the middle lobe or infraclavicular portions. Four of the 26 workers quickly succumbed. Four who were examined one-half to three-quarters of a year later showed very great extension of the pneumoconiotic changes. Reference is made to rapid appearance of symptoms even in premises where preventive measures seemed thorough. The author considers that there is no justification for treating lead poisoning as an occupational disease (presumably for purposes of compensation) while neglecting to treat silicosis in the same way.

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8 De Balsac, F. H., Agasse-Lafont, E., and Feil, A. La pneumoconiose des piqueurs de gres. C. R. Acad. Sci., vol. 186, 1928, pp. 1449-50. Quoted from Bulletin of Hygiene, vol. 3, No. 11, November, 1928, page 953.

9 v. Müller, Ernestine, Pneumoconiose bei Arbeitern eines Sandgebläses. Ztschr. f. Gewerbehyg.. u. Unfallverhütung, vol. 15, 1928, pp. 148-150. Quoted from Bulletin of Hygiene, vol. 3, No. 11, November, 1928, 953-954.

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Poland.- In a paper by Gadzikiewicz and Jaranowska[10] on the "Influence exerted on the health of miners by stone-dust used to prevent explosions in coal mines," the authors concluded that the stone-dust used, on account of its chemical composition, was not a menace to health. Where much dust is inhaled, trouble akin to that experienced by experimental animals may ensue; but ordinary conditions of mining do not favor such inhalation. Stone-dust used for preventing explosions is less harmful than the use of moisture; during dusting, respirators can always be worn, but steps should be taken to ensure that the dust used is free from microbic infection. A plea is put forward for collaboration between health authorities and research organizations in order to define the action of stone-dust, when mixed with coal-dust, upon the lungs.

Scotland.- In an article on the "Effects of coal-dust upon the silicotic lung," Cummins,[11] after noting previous opinions concerning the effect upon the lungs of inhaling coal-dust, gives particulars based upon post-mortem examination of the lungs of a coal miner. This man worked for four years with machine drills with exposure to silica-dust in what are known as hard headings, which are tunnels driven through rock in order to reach a seam of coal at another level. For the next five years he worked as an ordinary collier at the coal face. He came under observation for dyspnea with a cough, but no tubercle bacilli were found at any time in his sputum. During the last half of 1925 the dyspnea got worse and the patient got weaker until he finally died on March 11, 1926, with no edema of the ankles and no enlargement of the liver to indicate heart failure. The condition of the lungs is well illustrated by a radiograph taken before death and a section of the whole lung for comparison. Chemical analysis showed it to contain 10 per cent of ash of which 1.4 was silica. The lungs of an adult male who died from ordinary pulmonary tuberculosis gave 3.2 per cent ash containing a barely perceptible quantity of silica. The lungs showed microscopically pronounced fibrosis with blackening due to coal-dust far beyond what is ordinarily seen in coal miners' lungs. The tissue at the apices and the surface looked and felt like a lump of coal; and the lymph nodes were solid black from the carbon particles. Dust-containing macrophage cells were caught in the dense fibrous tissue in numerous collections. Many of them had broken up and left masses of dust particles free. The suggestion is put forward that this man first contracted silicotic fibrosis, which interfered with the lymph drainage of his lungs; subsequently, inhaled coal-dust was entangled in the tissue and unable to get away with the usual rapidity. Hence the accumulated coal-dust, acting like a foreign body, accentuated the effects of preexisting silicosis and led to the death of the patient. Normally coal-dust is got rid of from healthy lungs with such ease as to have earned it a reputation of being a harmless dust. The way in which the industrial exposure of the patient resembles that produced experimentally in animals by Mavrogordato is noted, and also that the results obtained are similar.

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10 Gadzikiewicz, W., and Jaranowska, Irena, Poudre pierreuse, appliquee dans les mines de charbon, pour prevenir les explosions et son ascendant sur la sante des mineurs. Archiwum Higjeny (Arch. d'Hygiene) Vilna, vol. 2, 1927. French summary 23-24. (In Polish 1-23.) (Hyg. Inst., Univ. Cracow.) Quoted from Bulletin of Hygiene, vol. 3, No. 3, March, 1928, page 228.

11 Cummins, S. L. Effects of Coal Dust Upon the Silicotic Lung. Jour. Pathol. and Bact., vol. 30, 1927, pp. 615-619.

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South Africa.- In the report of the subcommittee last year, in describing the work being done in South Africa, the figures were quoted down to and including the year 1923-1924. During that year there were a total number of 339 cases of silicosis - 319 simple silicosis and 20 silicosis with tuberculosis - and 11 cases of simple tuberculosis. In 1924-1925 there were 456 cases of silicosis - 428 cases of simple silicosis and 28 of silicosis with tuberculosis - and 18 cases of simple tuberculosis. During 1925-1926 there were a total of 497 cases of silicosis - 490 simple silicosis and 7 silicosis with tuberculosis - and 61 cases of simple tuberculosis. In 1926-1927 there were a total of 366 cases of silicosis - 364 simple silicosis and 2 silicosis with tuberculosis - and 42 cases of simple tuberculosis. Attention is called in the report of the Miners' Phthisis Medical Bureau for 1927[12] to the fact that as compared with previous years, there has been a marked decline in the number of cases of tuberculosis with silicosis and a rise in the number of cases returned as simple tuberculosis. In the opinion of Dr. Irvine, these changes are due to the increase in the relative importance of the tuberculous factor in the cases of compensatable disease now arising and of the increasingly close convergence of cases of incipient silico-tuberculosis and incipient simple tuberculosis in clinical and radiographic type, so that cases in which radiographic indications of the presence of both diseases appear simultaneously in a working miner are now rarely observed. In another statement on "The present position of miners' phthisis on the Rand,"[13] Dr. Irvine makes the forecast that the total production for 1927-1928 will not exceed 280 or 290 cases of simple silicosis. An interesting phase of the question is indicated in the statement[12] regarding the figures showing the influence of machine work upon the production of silicosis. The most representative figures are those for the miners working in their seventh to twelfth years. Among these the comparative attack-rates percentage is: No machines, 1.5; up to 50 per cent machines, 2.1; over 50 per cent machines, 8.9; the rates for machines only was 12.3 per cent, but this last figure was based upon very scanty numbers.

United States.- In the United States during the year, 1928, work was continued in the Tri-State district at the Picher, Okla., clinic under cooperative agreement by the U. S. Bureau of Mines, the Metropolitan Life Insurance Co., and the Tri-State Zinc and Lead Ore Producers Association. From June, 1927, to December 31, 1928, there were made 15,351 physical examinations of men and 400 of women and children. This year's work so far indicates that there has been a reduction in the number of silicotics working in the mines in this district. Much of this reduction is due to the silicotics' leaving the mines. A great many of these men have either been given suitable treatment in hospitals, sanitariums, etc., or have been provided with suitable work outside of the mines.

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12 Irvine, L. G., Report Upon the Work of the Miners' Phthisis Medical Bureau for the Year Ended 31st July, 1927. Union of South Africa, Pretoria, 1928.
13 Irvine, L. G., The Present Position of Miners' Phthisis on the Rand. Address delivered to the Association of Mine Managers, July 20, 1928.

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SUMMARY OF RECENT INVESTIGATIONS ON ABNORMAL AIR CONDITIONS

High Temperatures and Humidities

England.- In order to ascertain the association of sickness and other causes of absenteeism with temperature and other atmospheric conditions underground, a fairly extensive survey was made at each of ten pits.[14] Between October, 1925, and April, 1927, there were made 471 sets of observations, or about 47 per colliery. Of these observations, 230 were made at the coal face, 104 in the lesser haulage roads, 69 in the main haulage roads, and 18 at the pit bottom. On the whole, men working in the deeper pits suffered more sickness and accidents than those working in the shallower pits. There were no pits where the average temperature for the coal-face men was 70 to 74.9°, but those working at 75 to 79.9° suffered 50 per cent more sickness than the low-temperature workers, and the large group of men working in temperatures of 80° and upwards suffered 63 per cent more. The other underground workers showed corresponding increments of sickness with rise of temperature, though they were working under somewhat cooler conditions. The sickness appeared to increase rather more rapidly with rise of wet bulb than with rise of dry bulb temperature. The correlation of sickness with cooling power was smaller than its correlation with temperature. The reason is that the cooling power depends on air movement as well as on temperature, and increased air movement appears to increase sickness rather than diminish it, according to the authors of the report. They state that presumably the cause of the sickness depends, not on the high temperatures at which the miners perform their work, but on the sudden changes experienced when coming to the surface. Sometimes the surface air temperature is 50° lower than that underground near the coal face; an overheated and freely perspiring man, on emergence into such cold air, would be very liable to get chilled.

The correlation of accident frequency with dry bulb and wet bulb temperatures was fairly high for coal-face workers, and quite high for other underground workers. The correlation of accidents was, on the whole, lower than the correlation with temperatures because of the disturbing effect of the air velocity factor. While the accident frequency was practically constant at all velocities under 60 feet per minute, it showed a considerable increase at a mean velocity of 72 feet. The accident severity was high at very low velocities, but fell to a minimum at one of 30 to 59 feet per minute; then it rose rapidly, like the accident frequency. There can be no doubt that a certain amount of air movement is necessary for the attainment of maximum working capacity, according to the authors, and presumably the same condition holds for the attainment of minimum accident liability. Arguing from the small amount of evidence adduced, they concluded that probably accidents reach their minimum when the air currents have a comparatively low velocity, such as 30 to 60 feet per minute. As suggested in connection with the causation of sickness, their increase at higher velocities may be due to the men's tending to get chilled when they are temporarily resting from work. They would, in consequence, become stiffer and clumsier in their movements.

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14 Vernon, H. M., Bedford, T., and Warner, C. G., A Study of Absenteeism in a Group of Ten Collieries. The Colliery Guardian, August 31, 1928, pages 819-823.

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Attention is called to the marked inclination of the men working at high temperatures to go on compensation when they incurred an injury, the reason being given that probably the adverse atmospheric conditions induced a feeling of additional fatigue, from which they desired temporary relief.

At an informal meeting of the Institution of Civil Engineers, with regard to the methods of reducing temperature in deep mines, Mr. Whitehouse[15] said that increased ventilation would be adopted first, but that there were limitations to accomplishing this, owing to shaft capacities. He considered the elimination of moisture as of the highest importance. Consequently, shafts from which moisture could be excluded as far as possible should be adopted. Timbered shafts were not suitable for the working of deep deposits. The general cooling at the surface of ventilating air was a most convenient way of improving conditions, beyond the methods already referred to. General cooling underground had a disadvantage in that the extracted heat must be sent out of the mine either in the water pumped or in the upcast air. The quantity of water might be insufficient for this purpose, and it was often inconvenient to transfer the heat to the upcast shaft. The cooling by circulation of cold water introduced the practical difficulties of high pressure and power costs which render such a system unattractive. Local cooling with small plants offered distinct advantages, since over short distances less heat was taken up and a better effect was obtained at the working points. The disposal of the heat extracted, however, remained a difficult problem. Cooling by compressed air expanded in nozzles was uneconomical. There were similar objections to the use of compressed air expanded in an air engine doing external work. The combination of a compressor, an electric motor, and an air motor, mounted on one shaft, had been considered for local cooling and conditioning. The use of liquid air for cooling purposes was uneconomical. The use of ice sent from the surface was being more generally used for local cooling. By this method a reduction of 3° could be obtained at advanced points. The use of silica gel had been suggested for drying mine air, but the rise of temperature which took place made this method unattractive.

An interesting statement in regard to the effects on comfort of using local air movement instead of introducing fresh air from outside was made by Dudley[16] in connection with the use of the katathermometer at sea in the tropics. It was found that the use of an electric fan made more difference in comfort than extra air inlet; its effect upon heat loss was in the ratio of 50 per cent increase to only 20 per cent increase when a 3-inch pipe was made to deliver air into a small cabin. Hence the author suggests that power available aboard ship might be better devoted to circulating air than to introducing large amounts of fresh air, with a minimum of 50 cubic feet of fresh air per head per hour as the least amount to keep carbon dioxide below the deleterious level of 2 per cent.

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15 Whitehouse, , The Reduction of Temperature in Mines. The Colliery Guardian, December 28, 1928, page 2558.

16 Dudley, S. F., The Kata-Thermometer at Sea in the Tropics. Jour. Roy. Nav. M. Serv., vol. 14, 1928, pp. 77-103. Quoted from Bull. of Hyg., vol. 3, No. 8, August, 1928, page 671.

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Vernon[17] considers that the physical condition of the atmosphere, rather than its chemical composition, affects fatigue and efficiency more than any other environmental influence. Coal miners were noted to be longer in filling their tubs and to take more rest at high temperatures than at low, until their efficiency at 79° F. wet bulb was only 59 per cent of that at 66° F. wet bulb. Men rolling tinplates at hot furnace-work gave best output in winter and lowest in summer, with differences from 6.4 per cent at factories with cooling air douches, to 13.4 per cent at factories with no artificial ventilation. Evidence is quoted from iron and steel smelting to show that the hotter and heavier the work, the greater is the sickness experienced and also the mortality. Mortality among coal miners, particularly from respiratory diseases, is found to increase as they work in deeper and thus hotter pits. Atmospheric conditions affect the incidence of accidents as well as of sickness; in coal mines accidents may be twice as frequent in deep as in shallow workings. Generally a temperature of about 65 to 69° C. appears to give the best results for both accidents and output.

In regard to physiologic reactions, Campbell and Angus found[18] that, although there were some exceptions, on the whole the pulse rates increased as the temperature increased. The figures for still air were usually distinctly higher than those for moving air; also in moist air the pulse rates were higher than in dry air, and, further, in clothed subjects the pulse rates were higher than in the same subjects when naked. Skin temperature, perspiration, and amount of heat lost by evaporation were increased, while heat loss by conduction, convection, and radiation decreased. Wind opposed these effects in naked subjects only. Clothes increased these effects and antagonized the action of the wind. Movement of air and removal of clothes are the obvious remedies for such hot conditions. Moisture in the air, as compared with dry air, has no marked effect on perspiration at the higher temperatures studied. At 35° C., metabolism may or may not be increased. Wind, 500 feet per minute, at 20° C. definitely increased metabolism in naked subjects, owing to shivering; at higher temperatures there was no effect of wind on metabolism even in naked resting subjects. The evidence from researches in tropical climates does not indicate any increase in metabolism; on the contrary, many claim to have observed a decrease. The increase, when it is observed, then must be but a temporary effect, and is perhaps evidence of threatened uncompensated overheating.

Germany.- The interest of the Germans in the effects of exposure to abnormal temperatures and humidities is indicated by the issuance by Teleky in 1928[19] of a report in which he summarizes most of the important work done

17 Vernon, H. M., Industrial Fatigue in Relation to Atmospheric Conditions. Physiol. Rev., vol. 8, 1928, pp. 130-150. Quoted from Bull. of Hyg., vol. 3, No. 11, November, 1928, page 941.

18 Campbell, J. A., and Angus, T. C., Physiologic Reactions of Resting Subjects to Cooling Power and Effective Temperature. Jour. Indust. Hyg., vol. 10, December, 1928, pages 331-349.

19 Teleky, L., Englische und amerikanische Untersuchungen über Temperatur und Feuchtigkeit und deren Einfluss auf den Menschen. Mit besonderer Berücksichtigung von Gewerblichen und Bergwerksbetrieben. Ergebnisse der Hygiene Bakteriologie, Immunitätsforschung, und experimentellen Therapie, Berlin, 1928, pages 295-342.

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on this subject by investigators in the United States and England. In discussing the katathermometer, he considers that, while it is impossible, due to the complexity of the problem, to obtain an exact measure of the effects of atmospheric conditions on man through observation of inanimate objects, the katathermometer appears to be a very efficient and valuable instrument. The advantage of the effective temperature appears to him to lie in the fact that "it conforms more easily to our other conceptions, our usual methods of observation, and our legal definitions than does the kata value." In regard to the adaptation of the European to tropical climates he says that here also acclimatization takes place, which is also accompanied by decreased efficiency and performance and, with longer stay, a nervous exhaustion, an injury to the entire organism that, after two to five years' stay in the tropics, makes imperatively necessary a longer leave of absence for recovery and the necessity of final return to cooler zones by those growing old. There exists, also, doubtless the possibility of an adaptation to unfavorable temperature conditions in industrial operations and in the mines, which reduces momentarily the injury, just as is the case with acclimatization in the tropics; however, it may be also just as true that this does not prevent premature wearing out as a result of continued abnormal demands.

India.- According to David Penman,[20] principal of the School of Mines at Dhanbad, India, the Indian collier frequently has to work in a mine with a wet-bulb temperature of 85° C. or even higher. Moreover, the air in most of the working places in Indian mines is practically still, or at the best very sluggish; yet the miners work day after day uncomplainingly, and not only without mishaps, but apparently without any ill effects. Mr. Penman thinks it may be that the acclimatization of the Indian enables him to withstand heat in coal mines better than the average white man. The Indian miner, indeed, prefers to work in a warm place. He likes a gallery in which the temperature is 75° C., better than one in which it is 50°. Nor does he like to work in a strong breeze. He wears practically no clothing, whether the mine atmosphere is warm or cool; thus his whole body is exposed to the drying and cooling action of the air. He also works irregularly, remaining at work for about an hour, and then resting in a cooler place for 15 minutes or more. While actually at work he is a hard worker, though probably does not work at a rate equal to that of the British collier. He is, as a rule, shorter in stature and of much lighter build, and consequently expends less energy in physical exertion. But he dislikes any change in the temperature conditions to which he is accustomed, and would resent transfer from a place where the temperature is, say, 83° F. and the humidity 98 per cent to a place where the temperature is 20° lower.

Russia.- Experiments have been carried out on the influence of the amount of water drunk on the chlorine content of the sweat and blood of men in high temperatures,[21] and the effects on the physical condition of the blood

20 Penman, David, The Effect of High Temperatures on the Miner. British Medical Journal, November 10, 1928, pages 858-859.

21 Marschak, M., and Klaus, L., The Influence of the Amount of Water Drunk on the Chlorine Content of the Sweat and Blood of Man in High Temperature. Gigiena Truda, No. 9, 1927, pp. 14-22. Quoted from Jour. Indust. Hyg., vol.

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in high temperature produced by drinking water and saline solution.[22] In regard to the first, three series of experiments (72 in all) were carried out on six persons under the same air conditions: 46° C. dry bulb and 50 per cent relative humidity (corresponding to a wet kata cooling power of 2 millicalories per square centimeter per second, or 36° effective temperature). In the first series the subjects drank no water; in the second series the subjects drank 2 liters of tap water; and in the third series the subjects drank 2 liters of 1 per cent saline solution. The experiments in the first series lasted two hours; those in the second and third series, three hours. The sweat and blood tests were taken 40, 80, 120, 150, and 180 minutes after the subjects entered the experimental chamber (blood tests were also made before the subjects entered the chamber). The authors' findings show an increase in the chlorine concentration in the sweat depending on the duration of sweating; decrease in percentage of chlorine in whole blood and in serum, which is ascribed to a disturbance in the exchange of water-mineral solutions; water drunk during sweating produces a greater excretion of water and minerals; by drinking 1 per cent saline solution these disturbances are compensated.

In regard to the effects in high temperature on the physical condition of the blood produced by drinking water and saline solution, the authors made experiments on normal subjects in an experimental chamber at a temperature of from 40 to 46° C. and a relative humidity of 30 to 50 per cent. In one series the subjects were at rest and in the other they were engaged in physical work. Thirty to 60 minutes after the subjects entered the room a thinning of the blood occurred, followed by an increasing thickening of the blood as the experiment progressed. Most of the subjects could not remain in the chamber more than two hours. Drinking water had almost no effect on the physical condition of the blood; the subjects felt more comfortable, however, and were able to remain in the chamber as long as three hours. Introduction of saline solution caused a thinning of the blood that lasted during the three hours of the experiment. The comfort of the subjects was markedly increased. In physical work under the same conditions there occurred early a decided thickening of the blood which was little affected by drinking water but which disappeared entirely or almost entirely when salt was introduced into the system. By varying the amount of work and the temperature conditions, the authors noted that the resulting blood changes were not dependent on the duration of work but on the secretion of perspiration. The body temperature rose steadily throughout the experiment under the conditions of high temperature both during rest and during work. Drinking water and especially saline solution lessened the rise in temperature.

South Africa.- During 1927 there were no deaths from heat stroke in the Village Deep, although during the previous year there were six such deaths. In the City Deep there were four deaths during 1927, all of natives. According to the report of the government mining engineer[23] the absence of deaths

22 Marschak, M., and Dukelskaja, O., Effects on the Physical Conditions of the Blood in High Temperature Produced by Drinking Water and Saline Solution. Gigiena Truda, No. 1, 1928, pp. 29-38. Quoted from same source as reference 21 above.

23 Union of South Africa. Department of Mines and Industries, Annual Report of the Government Mining Engineer for the Calendar Year Ending December 31, 1927, Pretoria, 1928, page 67.

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at the Village Deep during 1927 was doubtless in part due to the precautions taken, which included probationary or acclimatization gangs for new natives, salt in drinking water, and meals underground; and perhaps also was partly due to injections of a preparation named "Lobelin" when symptoms of danger were noticed; but it was mainly due to the improved ventilation produced by the more powerful ventilating fans installed during 1926. Six nonfatal cases of collapse due to heat were reported from the City Deep, and two such cases from the Village Deep. The cases at the City Deep included an instructor and four apprentices in the Government Miners' Training School section. These are the only cases of Europeans yet reported. It was ascertained that each of the five persons was in either the inception or convalescent stage of mumps at the time of his collapse.

United States.- The Committee on Temperature, Humidity, and Air Motion of the American Society of Heating and Ventilating Engineers reported[24] that an investigation had been carried on in the psychrometric rooms at the Society's Research Laboratory to determine the rate of metabolism and the rate of evaporation from subjects under varying conditions of wet and dry bulb temperature and air movement. The object of this investigation was to obtain a rational basis for ventilation requirements, to determine the physiological reaction that occurs under these various conditions, and to tie them up if possible with the sensation of comfort as indicated by the comfort lines. As might have been anticipated, it has been found that the sensible heat, that is, the heat given off by radiation and convection as sensible heat to the air and surrounding objects, is a variable depending solely upon the differences between the average skin temperature and the temperature of the surroundings. The sensible heat varies not with the wet-bulb temperature, as might be supposed, but inversely with the dry-bulb temperature. That is, as the dry-bulb temperature of the air increases, the sensible heat given off decreases proportionately, and the latent heat removed by evaporation increases correspondingly. The reason for this apparently is, in so far as the skin is concerned, that the physiological control of evaporation is such as to regulate the amount of moisture given off to obtain the heat balance independently and regardless of the evaporating power of the air. A still more remarkable fact determined, and one whichwas contrary to our anticipation, was that there was very little relative variation in the metabolism or in the total heat given off under various atmospheric conditions, especially in the neighborhood of the comfort zone. However, for extreme conditions on either side of the comfort zone, the total heat given off by the body increased markedly. This would naturally be expected for the extreme temperatures below the comfort zone, but it also occurs in the extreme temperatures above the comfort zone. This latter effect undoubtedly is due to the extra effort of the circulatory and respiratory organs in their effort to maintain a temperature balance, and this extra effort undoubtedly was the cause of the increased metabolism and total heat produced. The sharp rise at this high effective temperature point is a pretty good indication of the breakdown of the physiological control system and occurs in effective temperature regions where it is probably impossible for human beings to exist permanently. While this does not primarily interest engineers engaged in the ventilation of buildings, yet it is of primary importance to those who are called upon

24 Carrier, W. H., Committee on Temperature, Humidity, and Air Motion. Jour. Am. Soc. Heat. and Vent. Engs., vol. 34, No. 2, February, 1928, pp. 145-149.

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to ventilate hot workrooms, mines, etc. All of this experimental work has been done with a view to determining the physiological reactions of subjects at rest. The next step will be to determine the physiological reactions of subjects at work. It is believed that this last research will complete the series of temperature, humidity, and air motion experiments necessary for determining some of the logical factors in heating, cooling, and ventilation.

Two manuscripts[25] have been prepared recently by members of the American Society of Heating and Ventilating Engineers in cooperation with the Bureau of Mines, one on the subject of "Heat and Moisture Loss from the Human Body and its Relation to Air Conditioning Problems," the other on "Thermal Exchanges between the Human Body and its Atmospheric Environment."

In experiments conducted by the Department of Ventilation and Illumination of the Harvard School of Public Health,[26] it was shown that standards of comfort, in so far as temperature, humidity, and air movement are concerned, are not absolute, but are considerably affected by climatic and other conditions. This variation appears to be caused by differences in the clothing worn in different climates and at different times of year, as well as by the adaptive physiologic changes that take place in man in response to climatic changes. In continuation of this work, experiments[27] were carried out to determine the summer comfort zone by experiments on a large group of men and women wearing customary warm weather clothing and engaged in sedentary pursuits. The comfort zone was determined as a result of 15 experiments, eight of which were conducted with progressively increasing room temperatures (usually in steps of 2 or 3° at a time) and the other seven with decreasing temperatures, in order that the probable optimum temperature might be approached from both the cool and the warm side of the zone. In this way adaptation to diurnal changes in air conditions was taken into account. In the course of the 15 tests, a total of 2,901 votes on sensations of comfort were obtained. The optimum temperature was found to follow the average monthly outdoor temperature. It remained at approximately the same value in July, August, and September, probably because the average monthly temperature did not vary much, although the prevailing outdoor temperature ranged from 70 to 99.5° F. A decrease in the optimum temperature became apparent only when the prevailing outdoor temperature fell to 66° F., which is below the customary room temperature in the United States for summer and winter. For practical use, the summer and winter comfort zones were superimposed upon the effective temperature chart designed at the Pittsburgh Laboratory of the American Society of Heating and Ventilating Engineers. By means of this new chart, the relative comfort of ordinary indoor conditions can be determined from the dry and wet bulb temperatures of the air.

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25 These papers have been submitted for publication.

26 Yaglou, C. P., The Comfort Zone for Men at Rest and Stripped to the Waist. Jour. Indust. Hyg., vol. 9, page 251.

27 Yaglou, C. P., and Drinker, Philip., The Summer Comfort Zone: Climate and Clothing. Jour. Indust. Hyg., vol. 10, No. 10, December, 1928, pages 350-363.

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SUMMARY OF SOME RECENT INVESTIGATIONS ON GASES FOUND IN MINES

Oxygen.- Oxygen, which has been used for years by the Bureau of Mines in treating cases of carbon monoxide poisoning, is just being discovered by the medical profession in general as an aid in the treatment of diseases, especially those in which anoxemia may be present. According to Dr. Evans of Buffalo, New York,[28] there are two reasons why the therapeutic value of pure oxygen has not, heretofore, been investigated clinically; one is that it has been considered an irritant gas if not greatly diluted; and the other is the high cost of medicinal oxygen. The use of oxygen in the industries has developed a practically pure gas and has reduced the price so that it can be administered at a comparatively low cost. The conclusion that oxygen is an irritant gas has been arrived at, says Dr. Evans, by the fact that small animals confined in an oxygen chamber in concentrations above 70 per cent develop a fatal pneumonia in from four to 14 days. Rabbits weighing 2 to 3 pounds and from one to two months old have been used chiefly in the experiments. They lived for several months in a 60 per cent oxygen mixture without suffering any ill effects, and from these experiments it was concluded that a human being should not be given more than a 60 per cent oxygen mixture, even in cases of pneumonia. According to him, the fear of giving enough oxygen normally to oxygenate the blood arises from an illogical application of facts. The oxyhemoglobin curve differs in rabbits from that in human beings and there is a vast difference in weight between an adult human being and an adult rabbit. There is also a matter of several years difference in age. The rabbits used were not suffering from pneumonia, their blood oxygen was normal, and their general health good. The pneumonia patient needs more than the usual amount of oxygen in the inhaled air to bring the blood oxygen up to normal in only a small percentage of pneumonia cases. The following conclusions have been reached by Dr. Evans[29] after application of oxygen therapy in actual cases: (1) The continuous administration of 60 to 100 per cent oxygen to anoxemic patients over periods as long as 18 days has proved beneficial and clinically without ill effects; (2) the 100 per cent of recoveries in the pneumonia group where oxygen was administered early, shows the advisability of employing oxygen therapy as soon as the diagnosis is made, whether cyanosis is present or not; (3) the inhalation of pure oxygen for one to several hours a day has been beneficial in cases of cardiac decompensation, asthma, hay fever, and extensive burns.

Carbon monoxide.- Recent investigations indicate that there is not much danger of carbon monoxide poisoning in unconfined spaces, such as congested city streets. Studies made by the U. S. Public Health Service[30] in 14 of the largest cities in the United States, having a combined population of of over 19,000,000, showed that in an average of 141 tests made in the city

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28 Evans, John J., Anesthesia and Inhalation Therapy as Combined Specialties. Med. Jour. and Rec., April 4, 1928.

29 Evans, John H., The Therapeutic Value of High Concentrations of Oxygen in Pneumonia, Cardiac Decompensation, Asthma, Hay Fever, and Other Diseases. Bull. Med. Soc., County of Erie and Buffalo Academy of Medicine, June, 1928.

30 Bloomfield, J. J., and Isbell, H. S., The Problem of Automobile Exhaust Gas in Streets and Repair Shops of Large Cities. Public Health Repts., vol. 43, No. 13, March 30, 1928, pp. 750-765.

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streets at peak hours of traffic there was a concentration of 0.8 part of carbon monoxide per 10,000 parts of air. Only 24 per cent of all the street samples had more than 1 part of carbon monoxide in 10,000 of air, and in only one location, a covered passageway, was there as much as 2 parts per 10,000. The investigatiors concluded that the only individual who may possibly be exposed to a health hazard from inhaling street air containing automobile exhaust gas is the traffic officer, and this potential hazard may be minimized by diminishing the duration of exposure at the most congested traffic stations.

Similar investigations made in Paris[31] showed that, even in the streets where the traffic is dense, concentrations of carbon monoxide less than 1 in 100,000 were found above the third story and that at 1.6 meters above the ground on the sidewalk, the concentration of carbon monoxide did not exceed 3 to 4 in 100,000 in the most frequented streets.

During 1926-1928 the Bureau of Sanitary Engineering of the Chicago Department of Health[32] undertook a comprehensive study of air pollution by carbon monoxide in the streets of the city. Samples were collected at the curb instead of in the middle of the street, because the greater number of people exposed are upon the sidewalks and in the adjacent offices and stores. Of 649 samples examined, 85 per cent showed 0.5 part or less per 10,000 parts of air, and 63 per cent showed 0.3 part or less per 10,000. The average concentration of all the samples was 0.31 part of carbon monoxide per 10,000 parts of air. Recommendations included desirability of study of mechanical ventilating systems as a part of the design of all double-decked streets for use by automobiles and the restriction of the idling of motors on the streets to a minimum and, if the idling can not be prevented, it was pointed out that at least it should not be allowed near air intakes for ventilating systems.

Studies, mentioned in last year's report, were continued by the Bureau of Mines in cooperation with the New York State Bridge and Tunnel Commission and the New Jersey Interstate Bridge and Tunnel Commission on the effects of repeated daily exposure to carbon monoxide during long periods, such as traffic officers or maintenance men might experience in the tunnels, the previous investigation having been directed toward the effect of occasional and relatively short exposures to exhaust gas. The following is a summary of the results of the investigations of long exposure to low concentrations of carbon monoxide.[33]

Six men were exposed 4 to 7 hours daily over a period of 68 days to gasoline engine exhaust gas-air mixtures containing 2, 3, and 4 parts of carbon monoxide per 10,000 parts of air.

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31 Florentin, Daniel, Sur la compostion de l'air des rues de Paris. Compt. rend. des séances de L'Academie des Sciences, vol. 185, No. 25, December, 1927, pp. 1538-1541.
Cambier, R., and Marcy, F., Same title and reference as 31 above, vol. 186, No. 13, March 26, 1928, pp. 918-921.

32 Connolly, J. I., Martinek, M. J., and Aeberly, J. J., The Carbon Monoxide Hazard in City Streets. Am. Jour. Pub. Health, vol. 8, No. 11, Nov., 1928, pp. 1375-1383.

33 Sayers, R. R., Yant, W. P., Levy, Edward, and Fulton, W. B., Effect of Repeated Daily Exposure of Several Hours to Small Amounts of Automobile Exhaust Gas. U. S. Public Health Bull. 186, 1929.

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Exposure to 2 part of CO in 10,000 of air caused some subjects at rest or exercising mildly to experience slight but not discomforting symptoms in approximately 2 hours and distinct frontal headaches of a discomforting nature in 3½ to 4 hours. No symptoms of any type were experienced in more than 50 per cent of the exposures, and no occipital headaches occurred in any subjects even after 6½ hours' exposure. The blood attained 20 per cent carbon monoxide hemoglobin in 3¼ to 4½ hours and 25 per cent in 5 to 6 hours, depending on the person and whether he was at rest or exercising mildly. Saturation above 25 per cent was attained very slowly.

Exposure to 3 parts in 10,000 caused some subjects at rest or exercising mildly to experience slight symptoms in less than 2 hours and distinct frontal headaches in 2½ to 3 hours. A few occipital headaches and cases of vertigo occurred after 3 hours. In more than 65 per cent of the cases distinct discomforting symptoms were experienced after 5 hours' exposure. This concentration produced 20 per cent carbon monoxide hemoglobin in the blood in 2½ to 3½ hours, 25 per cent in 3 to 4 hours, and 30 per cent in 4 to 4½ hours, depending on the subject and whether he is at rest or exercising.

Exposure to 4 parts in 10,000 caused some subjects to experience frontal headaches in 1½ to 2 hours. A few occipital headaches occurred in 2½ to 3½ hours. At the end of 3½ to 4 hours more than 90 per cent had distinct frontal headaches. The blood attained 20 per cent carbon monoxide hemoglobin in 1½ to 2½ hours, 25 per cent in 2½ to 3½ hours, and 30 per cent in 3 to 4 hours, depending on the subject and whether he was at rest or exercising mildly.

Although there was a tendency for headaches to appear with a lower amount of carbon monoxide hemoglobin when the latter was attained by exposure to the lower concentrations of carbon monoxide, in general frontal headaches just begin in some subjects when the saturation reaches 18 to 20 per cent. A few occipital headaches accompanied by vertigo distinctly occurred at 23 to 28 per cent.

Exercise, even though of a mild form, distinctly augments the absorption of carbon monoxide and causes symptoms to appear after shorter exposure.

The rate of elimination of carbon monoxide from the blood in a given period after exposure varied directly with the initial saturation, but for the initial saturations attained in this study the rate of elimination appears the same for the same range of saturations; that is, it is the same between, say, 25 and 20 per cent, almost regardless of whether the initial saturation was 35, 30, or 35 per cent. After an initial saturation of 35 per cent was attained it required approximately one-half hour to lower it to 30 per cent, about 1 hour to lower it to 25 per cent, nearly 1½ hours to lower it to 20 per cent, nearly 2 hours more to lower it to 15 per cent, 2½ hours more to lower it to 10 per cent, and 3 to 5 hours longer to lower the saturation to 5 per cent, if the subject breathed air the entire time. For lower initial saturation the time was the same as the portion of the above which succeeds the value in question.

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A 30-minute inhalation of oxygen or 5 per cent carbon dioxide in oxygen reduced the amount of carbon monoxide hemoglobin from 35 per cent to less than 10 per cent in 30 minutes, and when given immediately it alleviated the symptoms. For lower initial saturations the same effect was produced in somewhat less time.

Exercise immediately after exposure markedly increased the speed of elimination. This procedure however is not recommended or advised as a treatment for poisoning by carbon monoxide.

There were no apparent signs that the tests produced deleterious effects on the health and physical well-being of the subjects. No lack of appetite, change of weight, or muscular weakness occurred. In general, a distinct increase in hemoglobin occurred, and was accompanied by an increase in red blood cells. No important change occurred in the leucocytes. With the exception of a few occurrences of traces of sugar, no important changes or abnormalities were noted in the urine. Tests for blood pigment were negative.

The efficacy of the ventilating system installed in the Holland Tunnel in preventing accumulation of dangerous concentrations of carbon monoxide from the exhaust gas of motor vehicles in indicated by the first year's experience. On the opening day the ventilation system, as indicated in last year's report, was subjected to a rather severe test and met this test satisfactorily. With the opening-day rush over and traffic settling down to more normal conditions, it was apparent, with the extremely good air conditions in the tunnel on the first day, that the ventilation could be reduced. This was gradually done by slowing down the fans and by shutting down some of them. According to Mr. Singstad,[34] ventilation during the last six-month period of the first year of operation, with a total of 4,866,781 vehicles using the tunnel, has been provided on the basis of the carbon monoxide not exceeding $2\frac{1}{2}$ parts per 10,000 for a period of five minutes in any of the 14 sections of the tunnel. The average carbon monoxide content during that period has been much below this figure. Adequate ventilation has required the operation of only one fan at half speed on each duct except during certain periods of the day when increased ventilation has been provided on certain sections either by running one fan at higher speed or operating two fans of each set of three fans which form the full operating capacity of the ventilating system.

34 Singstad, Ole, A Year's Operating Experience With the Holland Vehicular Tunnel. Eng. News-Record, December 27, 1928.

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